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Demonstration of 10.7-Gb/s transmission in 50-km PON with Uncooled Free-Running 1550-nm VCSEL

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Abstract: First-known demonstration of an uncooled, free-running 1550 nm VCSEL at 10.7 Gb/s over 50 km PON uplink with 35 km SMF and 15 km inverse dispersion fiber, achieving 24 dB margin for 10^{-9} BER.

OCIS Codes: (060.4250) Networks; (060.4510) Optical communications.

1. Introduction

VCSEL device optimization has recently been the focus of much effort to realize low-cost, high-bandwidth optical sources for photonics [1,2]. This has resulted in the development of stable, uncooled 10-GHz devices for operation in the low-attenuation wavelength region of currently-installed single-mode fiber (SMF); to date the practical range of such demonstrations has been limited to modest link lengths, or required sophisticated optical injection locking (OIL) [3,4] to overcome limitations imposed by dispersive transmission of the chirped signal.

We present error-free 50 km transmission at 10.7 Gb/s with no use of OIL or temperature control. We utilized a commercially-available 10 GHz VCSEL device, ideal for low-cost WDM-PON. The uncooled device operates at 1551 nm wavelength, and we achieved error-free transmission (with bit error rate, BER, of 10^{-9}) over 50 km PON at a data rate of 10.7 Gb/s. At this BER threshold, transmission over 35 km SMF (with dispersion, D=595 ps/nm at 1550 nm) was achieved with 6 dB power penalty. The link reach was extended by a dispersion-matched span of 15 km inverse-dispersion fiber (IDF), yielding net D of -0.59 ps/nm; we observed negligible system penalty with pseudo-random binary sequence (PRBS) of length $L_1=2^7-1$, $L_2=2^{23}-1$ and $L_3=2^{31}-1$ bits. Offset filtering at the receiver allowed record system performance to be achieved by exploiting the adiabatic chirp of the VCSEL output.

2. System Description

We consider a PON uplink: the experimental layout is shown in Fig. 1. We implemented an uncooled VCSEL as the optical transmitter at the ONU as shown and a pre-amplified receiver at the central office (CO). When modulated, the VCSEL provided +1 dBm average output power with an extinction ratio (ER) of 2.4 dB; laser spectra are shown Fig. 1 (inset), at 0.05 nm resolution. The 20 dB bandwidth of the modulated signal is within 0.2 nm.

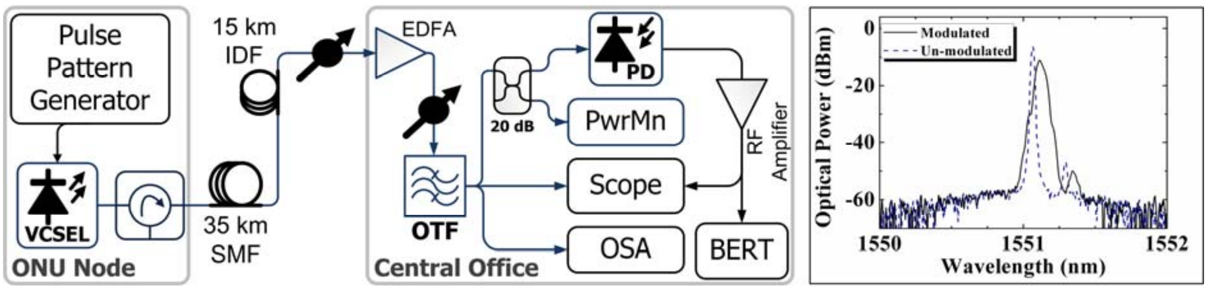

Figure 1: Experimental layout. IDF, inverse dispersion singlemode fiber; OTF, optical tunable bandpass filter; PwrMn, optical power monitor; OSA, optical spectrum analyzer; BERT, bit error rate tester. Inset reports modulated (solid) and un-modulated (dash) optical transmitter spectra.

Transmission was done over 35 km SMF, and a matching 15 km IDF.The receiver implemented a 35 dB low-noise EDFA, with an optical tunable filter (OTF) to remove out-of-band ASE noise; offset filtering of the received spectra also allows improvement of the recovered BER by exploiting the adiabatic chirp of the source to improve the extinction ratio at the 10 GHz photo-detector (PD). The received signal waveform and spectrum were recorded using oscilloscope and optical spectrum analyzer (OSA) respectively. The PD was operated below saturation, with constant optical power. Post-PD RF signal amplification provided suitable peak-to-peak voltage swing to the BERT.

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3. Results

We assessed BER response to average received power with PRBS of various lengths, and report the results in Fig. 2.

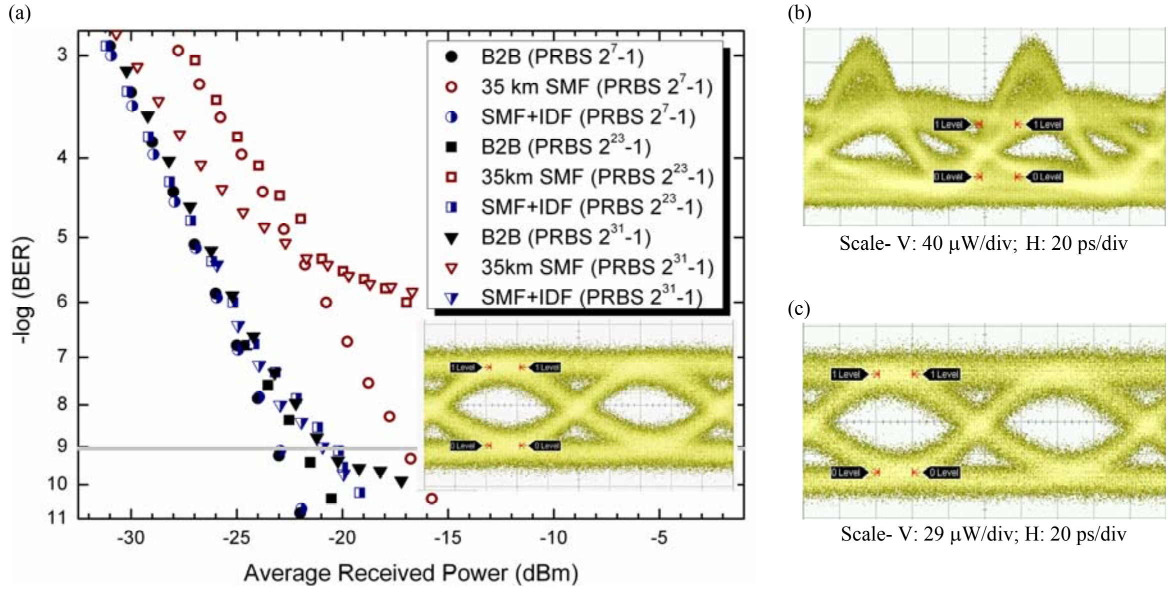

Figure 2: (a) Receiver BER as a function of receiver power for different PRBS, at points along the PON uplink: back to back (B2B), after 35 km SMF and after 50 km combined SMF+IDF. Inset shows eye diagram at VCSEL (2.4 dB extinction ratio, ER. Scale: V:20 μW/div, H: 20 ps/div). **(b)** Eye diagram after 35 km SMF (1.73 dB ER) and **(c)** after 50 km transmission over SMF+IDF (2.4 dB ER).

We achieved error-free transmission under all transmission conditions evaluated with PRBS of length 2^7-1 bits (circle); 6 dB power penalty was observed for error free transmission after the SMF: negligible power penalty was observed after the combined SMF and IDF. After 35 km SMF, short data sequence was transmitted error free but a noise floor at BER of 10^{-6} was observed for data sequences of lengths 2^{23}-1 (square) and 2^{31}-1 bits (triangle). These effects were not observed after the IDF, and negligible transmission power penalty was observed after 50 km. System margin for error-free performance was observed to be 24 dB.

The noise floor associated with SMF transmission of long pattern lengths is likely due to increased transient chirp produced by the longer runs of zeroes and ones in long PRBS; the result after dispersive transmission is a closed eye diagram and increased penalty. This effect was absent after the inclusion of IDF, and noted a clear opern eye after 50 km. Field-deployable IDF technology is therefore attractive for expanding existing-generation networks towards achieving future extended-reach PON topologies.

4. Conclusion

We have demonstrated error-free transmission of 10.7 Gb/s over a 50 km PON with a single uncooled VCSEL as the optical source. Inverse dispersion fiber was used to overcome the effects of transmission, and allow error-free transmission with negligible transmission penalty at the output of the combined fiber link even with long PRBS sequences (of length 2^{31}-1 bits). System margin was observed better than 20 dB for all PRBS lengths used. These results indicate the feasibility of VCSEL and deployable IDFto realize long-reach next-generation PON systems.

5. References

[1] E. Kapon and A. Sirbu, “Long-wavelength VCSELs: Power-efficient answer,” Nature Photon., **3** (2009).
[2] F. Koyama, “Recent Advances of VCSEL Photonics,” J. Lightw. Technol., **24**, 4502-4513 (2006).
[3] P. Boffi et al. “VCSEL to VCSEL Injection Locking for Uncompensated 40-km Transmission at 10 Gb/s,” in Proc OFC, 2009, JThA32.
[4] D. Parekh et al., “90-km Single-Mode Fiber Transmission of 10-Gbs Multimode VCSELs under Optical Injection Lock.” in Proc. OFC 2009.

5. Acknowledgements

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